

Aristarchus of Samos

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Aristarchos of Samos, [Aristotle University, Thessaloniki](#)/Greece

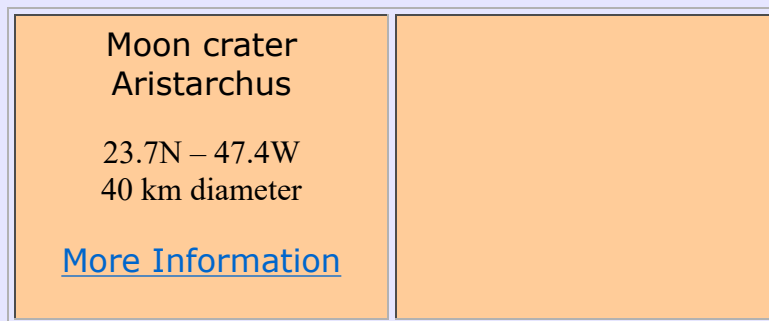
Aristarchus ([Ἀρίσταρχος](#)) (310 BC - circa 230 BC) was a Greek astronomer and mathematician, born in [Samos, Greece](#). He is the first recorded person to propose a heliocentric model of the solar system, placing the Sun, not the Earth, at the center of the known universe (hence he is sometimes known as the "Greek Copernicus"). His astronomical ideas were not well-received and were subordinated to those of [Aristotle](#) and [Ptolemy](#), until they were successfully revived and developed by Copernicus nearly 2000 years later.

The only work of Aristarchus which has survived to the present time, *On the Sizes and Distances of the Sun and Moon*, is based on a geocentric worldview. We know through citations, however, that Aristarchus wrote another book in which he advanced an alternative hypothesis of the heliocentric model.

Archimedes wrote:

"You King Gelon are aware the 'universe' is the name given by most astronomers to the sphere the centre

of which is the center of the Earth, while its radius is equal to the straight line between the center of the Sun and the center of the Earth. This is the common account as you have heard from astronomers. But Aristarchus has brought out a book consisting of certain hypotheses, wherein it appears, as a consequence of the assumptions made, that the universe is many times greater than the 'universe' just mentioned. His hypotheses are that the fixed stars and the Sun remain unmoved, that the Earth revolves about the Sun on the circumference of a circle, the Sun lying in the middle of the orbit, and that the sphere of fixed stars, situated about the same center as the Sun, is so great that the circle in which he supposes the Earth to revolve bears such a proportion to the distance of the fixed stars as the center of the sphere bears to its surface."



Aristarchus thus believed the stars to be infinitely far away, and saw this as the reason why there was no visible [parallax](#), that is, an observed movement of the stars relative to each other as the Earth moved around the Sun. The stars are in fact much farther away than was assumed in ancient times, which is why stellar parallax is only detectable with telescopes. But the geocentric model was assumed to be a simpler, better explanation for the lack of parallax. The rejection of the heliocentric view was apparently quite strong, as the following passage from Plutarch suggests (On the Apparent Face in the Orb of the Moon):

"[Cleanthes, a contemporary of Aristarchus] thought it was the duty of the Greeks to indict Aristarchus of Samos on the charge of impiety for putting in motion the Hearth of the universe [i.e. the earth], . . . supposing the heaven to remain at rest and the earth to revolve in an oblique circle, while it rotates, at the same time, about its own axis."

Size of the Moon

Aristarchus observed the Moon moving through the Earth's shadow during a lunar eclipse. He estimated that the diameter of the Earth was 3 times the Moon's diameter. Using [Eratosthenes'](#) calculation that the Earth was 42,000 km in circumference, he concluded that the Moon was 14,000 km in circumference. The Moon has a circumference of about 10,916 km.

Distance to the Sun

Aristarchus argued that the Sun, Moon, and Earth form a near right triangle at the moment of first or last quarter moon. He estimated that the angle was 87° . Using correct geometry, but inaccurate observational data, Aristarchus concluded that the Sun was 20 times farther away than the Moon. The Sun is actually about 390 times farther away. He pointed out that the Moon and Sun have nearly equal apparent angular sizes and therefore their diameters must be in proportion to their distances from Earth. He thus concluded that the Sun was 20 times larger than the Moon. This is also incorrect, although logical. It does, however, suggest that the Sun is clearly larger than the Earth, which can be taken to support the heliocentric model.

See also: [Aristarchus, a bright crater on the Moon](#), and asteroid 3999 Aristarchus, both named after the astronomer.

Links

Aristarchus of Samos (<http://www-gap.dcs.st-and.ac.uk/~history/Mathematicians/Aristarchus.html>)

Biography: JRASC, 75 (1981) 29
(<http://adsabs.harvard.edu/full/seri/JRASC/0075/0000029.000.html>)

[Heliocentric Ideas of ancient Greeks and Copernicus](#)

Sir Thomas Heath , Aristarchus of Samos : The Ancient Copernicus Dover Publications, ISBN: 0486438864

In Greek

Βρέθηκε χαμένο έργο αρχαίου αστρονόμου Ένα χαμένο έργο του Αρίσταρχου τού Σάμιου (2ος αι.

π.Χ.), φαίνεται πως περιέχεται σε αραβικό κώδικα που εντοπίστηκε πριν σε βιβλιοθήκη της Τεχεράνης

.....

We are told that Aristarchus of Samos was a pupil of Strato of Lampsacus, a natural philosopher of originality, who succeeded Theophrastus as head of the Peripatetic school in 288 or 287 B.C., and held that position for eighteen years. Two other facts enable us to fix Aristarchus's date approximately. In 281 -280 he made an observation of the summer solstice ; and the book in which he formulated his heliocentric hypothesis was published before the date of Archimedes's *Psammmites* or *Sandreckoner*, a work written before 216 B.C. Aristarchus therefore probably lived circa 310-230 B.C., that is, he came about seventy-five years later than Heraclides and was older than Archimedes by about twenty five years.

Aristarchus was called "the mathematician," no doubt in order to distinguish him from the many other persons of the same name ; Vitruvius includes him among the few great men who possessed an equally profound knowledge of all branches of science, geometry, astronomy, music, etc. " Men of this type are rare, men such as were in times past Aristarchus of Samos, Philolaus and Archytas of Tarentum, Apollonius of Perga, Eratosthenes of Cyrene, Archimedes and Scopinas of Syracuse, who left to posterity many mechanical and gnomonic appliances which they invented and explained on mathematical and natural principles." That Aristarchus was a very capable geometer is proved by his extant book, *On the sizes and distances of the sun and moon*, presently to be described. In the mechanical line he is credited with the invention of an improved sun-dial, the so-called scaphe, which had not a plane but a concave hemispherical surface, with a pointer erected vertically in the middle, throwing shadows and so enabling the direction and height of the sun to be read off by means of lines marked on the surface of the hemisphere. He also wrote on vision, light, and colours. His views on the latter subjects were no doubt largely influenced by the teaching of Strato. Strato held that colours were emanations from bodies, material molecules as it were, which imparted to the intervening air the same colour as that possessed by the body. Aristarchus said that colours

are " shapes or forms stamping the air with impressions like themselves as it were," that " colours in darkness have no colouring," and that " light is the colour impinging on a substratum ".

THE HELIOCENTRIC HYPOTHESIS.

There is no doubt whatever that Aristarchus put forward the heliocentric hypothesis. Ancient testimony is unanimous on the point, and the first witness is Archimedes who was a younger contemporary of Aristarchus, so that there is no possibility of a mistake. Copernicus himself admitted that the theory was attributed to Aristarchus, though this does not seem to be generally known. Copernicus refers in two passages of his work, *De revolutionibus caelestibus*, to the opinions of the ancients about the motion of the earth. In the dedicatory letter to Pope Paul III he mentions that he first learnt from Cicero that one Nicetas (i.e. Hicetas) had attributed motion to the earth, and that he afterwards read in Plutarch that certain others held that opinion ; he then quotes the *Placita philosophorum* according to which " Philolaus the Pythagorean asserted that the earth moved round the fire in an oblique circle in the same way as the sun and moon ". In Book I. c. 5 of his work Copernicus alludes to the views of Heraclides, Ecphantus, and Hicetas, who made the earth rotate about its own axis, and then goes on to say that it would not be very surprising if any one should attribute to the earth another motion besides rotation, namely, revolution in an orbit in space : " *atque etiam (terram) pluribus motibus vagantem et unam ex astris Philolaus Pythagoricus sensisse fertur, Mathematicus non vulgaris*". Here, however, there is no question of the earth revolving round the sun, and there is no mention of Aristarchus. But Copernicus did mention the theory of Aristarchus in a passage which he afterwards suppressed : " *Credibile est hisce similibusque causis Philolaum mobilitatem terrae sensisse, quod etiam nonnulli Aristarchum Samium ferunt in eadem fuisse sententia* ". It is desirable to quote the whole passage of Archimedes in which the allusion to Aristarchus's heliocentric hypothesis occurs, in order to show the whole context.

" You are aware [' you ' being King Gelon] that "

universe ' is the name given by most astronomers to the sphere the centre of which is the centre of the earth, while its radius is equal to the straight line between the centre of the sun and the centre of the earth. This is the common account as you have heard from astronomers. But Aristarchus brought out a book consisting of certain hypotheses, wherein it appears, as a consequence of the assumptions made, that the universe is many times greater than the * universe ' just mentioned. His hypotheses are that the fixed stars and the sun remain unmoved, that the earth revolves about the sun in the circumference of a circle, the sun lying in the middle of the orbit > and that the sphere of the fixed stars, situated about the same centre as the sun, is so great that the circle in which he supposes the earth to revolve bears such a proportion to the distance of the fixed stars as the centre of the sphere bears to its surface."

The heliocentric hypothesis is here stated in language which leaves no room for doubt about its meaning. The sun, like the fixed stars, remains unmoved and forms the centre of a circular orbit in which the earth moves round it ; the sphere of the fixed stars has its centre at the centre of the sun.

We have further evidence in a passage of Plutarch's tract, *On the face in the moon's orb* : " Only do not, my dear fellow, enter an action for impiety against me in the style of Cleanthes, who thought it was the duty of Greeks to indict Aristarchus on the charge of impiety for putting in motion the Hearth of the Universe, this being the effect of his attempt to save the phenomena by supposing the heaven to remain at rest and the earth to revolve in an oblique circle, while it rotates, at the same time, about its own axis ".

Here we have the additional detail that Aristarchus followed Heraclides in attributing to the earth the daily rotation "about its axis ; Archimedes does not state this in so many words, but it is clearly involved by his remark that Aristarchus supposed the fixed stars as well as the sun to remain unmoved in space. A tract " *Against Aristarchus* " is mentioned by Diogenes Laertius among Cleanthes's works ; and it was evidently published during Aristarchus's lifetime (Cleanthes died about 232 B.C.).

We learn from another passage of Plutarch that the hypothesis of Aristarchus was adopted, about a century later, by Seleucus, of Seleucia on the Tigris, a Chaldaean or Babylonian, who also wrote on the subject of the tides about 150 B.C. The passage is interesting because it also alludes to the doubt about Plato's final views.

" Did Plato put the earth in motion as he did the sun, the moon and the five planets which he called the ' instruments of time ' on account of their turnings, and was it necessary to conceive that the earth 'which is globed about the axis stretched from pole to pole through the whole universe ' was not represented as being (merely) held together and at rest but as turning and revolving, as Aristarchus and Seleucus afterwards maintained that it did, the former of whom stated this as only a hypothesis, the latter as a definite opinion ? "

No one after Seleucus is mentioned by name as having accepted the doctrine of Aristarchus and, if other Greek astronomers refer to it, they do so only to denounce it. Hipparchus, himself a contemporary of Seleucus, definitely reverted to the geocentric system, and it was doubtless his authority which sealed the fate of the heliocentric hypothesis for so many centuries.

The reasons which weighed with Hipparchus were presumably the facts that the system in which the earth revolved in a circle of which the sun was the exact centre failed to "save the phenomena," and in particular to account for the variations of distance and the irregularities of the motions, which became more and more patent as methods of observation improved ; that, on the other hand, the theory of epicycles did suffice to represent the phenomena with considerable accuracy ; and that the latter theory could be reconciled with the immobility of the earth.

ON THE APPARENT DIAMETER OF THE SUN.

Archimedes tells us in the same treatise that " Aristarchus discovered that the sun's apparent size is about part of the zodiac circle " ; that is to say, he observed that the angle subtended at the earth by the diameter of the sun is about half a degree.

ON THE SIZES AND DISTANCES OF THE SUN AND

MOON.

Archimedes also says that, whereas the ratio of the diameter of the sun to that of the moon had been estimated by Eudoxus at 9 : 1 and by his own father Phidias at 12 : 1, Aristarchus made the ratio greater than 18 : 1 but less than 20 : 1. Fortunately we possess in Greek the short treatise in which Aristarchus proved these conclusions ; on the other matter of the apparent diameter of the sun Archimedes's statement is our only evidence.

It is noteworthy that in Aristarchus's extant treatise *On the sizes and distances of the sun and moon* there is no hint of the heliocentric hypothesis, while the apparent diameter of the sun is there assumed to be, not $1/2$ degree, but the very inaccurate figure of 2 degree. Both circumstances are explained if we assume that the treatise was an early work written before the hypotheses described by Archimedes were put forward. In the treatise Aristarchus finds the ratio of the diameter of the sun to the diameter of the earth to lie between 19:3 and 43 : 6 ; this would make the volume of the sun about 300 times that of the earth, and it may be that the great size of the sun in comparison with the earth, as thus brought out, was one of the considerations which led Aristarchus to place the sun rather than the earth in the centre of the universe, since it might even at that day seem absurd to make the body which was so much larger revolve about the smaller.

There is no reason to doubt that in his heliocentric system Aristarchus retained the moon as a satellite of the earth revolving round it as centre ; hence even in his system there was one epicycle.

The treatise *On sizes and distances* being the only work of Aristarchus which has survived, it will be fitting to give here a description of its contents and special features.

The style of Aristarchus is thoroughly classical as befits an able geometer intermediate in date between Euclid and Archimedes, and his demonstrations are worked out with the same rigour as those of his predecessor and successor. The propositions of Euclid's *Elements* are, of course, taken for granted, but other things are tacitly assumed which go beyond

what we find in Euclid. Thus the transformations of ratios defined in Euclid, Book V, and denoted by the terms inversely, alternately, componendo, convertendo, etc., are regularly used in dealing with unequal ratios, whereas in Euclid they are only used in proportions, i.e. cases of equality of ratios. But the propositions of Aristarchus are also of particular mathematical interest because the ratios of the sizes and distances which have to be calculated are really trigonometrical ratios, sines, cosines, etc., although at the time of Aristarchus trigonometry had not been invented, and no reasonably close approximation to the value of π , the ratio of the circumference of any circle to its diameter, had been made (it was Archimedes who first obtained the approximation $22/7$). Exact calculation of the trigonometrical ratios being therefore impossible for Aristarchus, he set himself to find upper and lower limits for them, and he succeeded in locating those which emerge in his propositions within tolerably narrow limits, though not always the narrowest within which it would have been possible, even for him, to confine them. In this species of approximation to trigonometry he tacitly assumes propositions comparing the ratio between a greater and a lesser angle in a figure with the ratio between two straight lines, propositions which are formally proved by Ptolemy at the beginning of his *Syntaxis*. Here again we have proof that textbooks containing such propositions existed before Aristarchus's time, and probably much earlier, although they have not survived.

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